CHAPTER 8

CONSTRUCTION TECHNIQUES AND INSPECTION

8-1. Minimization of foundation problems from construction

Many problems and substandard performance of foundations observed in structures on expansive soils occur from poor quality control and faulty construction practice. Much of the construction equipment and procedures that are used depends on the foundation soil characteristics and soil profiles. Careful inspection during construction is necessary to ensure that the structure is built according to the specifications.

a. *Important elements of construction techniques.* Construction techniques should be used that promote a constant moisture regime in the foundation soils during and following construction. The following elements of construction are important in obtaining adequate foundation performance in expansive soils.

(1) *Excavations.* The excavation should be completed as quickly as possible to the design depth and protected from drying. An impervious moisture barrier should be applied on the newly exposed surfaces of the excavation to prevent drying of the foundation soils immediately after excavating to the design depth. Sides of the excavation should be constructed on a lV on lH slope or an appropriate angle that will not transmit intolerable swelling pressures from the expansive soil to the foundation. The foundation should be constructed in the excavation as quickly as practical.

(2) *Selection of materials.* Selected materials should conform to design requirements.

(a) Backfills should be nonswelling materials.

(b) Concrete should be of adequate strength and workability.

(c) Reinforcing steel should be of adequate size and strength.

(d) Moisture barriers should be durable and impervious.

(3) *Placement of materials.* All structural materials should be positioned in the proper location of the foundation.

(4) *Compaction of backfills.* Backfills of natural expansive soil should be compacted to minimize effects of volume changes in the fill on performance of the foundation. Backfills should not transmit intolerable swell pressures from the natural expansive foundation soil to basement or retaining walls.

(5) *Drainage during construction.* The site should be prepared to avoid ponding of water in low areas. Consideration should be given to compaction of 6 to 12 inches or more of impervious nonswelling soil on the site prior to construction of the foundation to promote drainage and trafficability on the site. Dehydrated lime may also be sprinkled on the surface of expansive soil to promote trafficability. Sumps and pumps should be provided at the bottom of excavations if necessary to remove rainwater or subsurface drainage entering the excavation. Provision for after normal duty operation of the pumps should also be made.

(6) *Permanent drainage.* Grades of at least 1 percent and preferably 5 percent, to promote drainage of water away from the structure, should be provided around the perimeter of the structure. Low areas should be filled with compacted backfill. Runoff from roofs should be directed away from the structure by surface channels or drains. Subsurface drains should be constructed to collect seepage of water through pervious backfills placed adjacent to the foundation.

b. Considerations of construction inspection. Table 8-1 lists major considerations of construction inspection. Inspections related to concrete reinforced slab and drilled shaft foundations, the two most commonly used foundations in expansive soil areas, are discussed below.

8-2. Stiffened slab foundations

Items in table 8-2 should be checked to minimize defective slab foundations.

a. The inspector should check for proper site prep aration and placement of the moisture barrier, steel, and concrete. All drainage systems should be inspected for proper grade and connections to an outlet.

b. Posttensioned slabs require trained personnel and careful inspection to properly apply the posttensioning procedure. For example, anchors for the steel tendons should be placed at the specified depth (lower than the depth of the tensioning rods) to avoid pullout during tensioning. Tendons should be stressed 3 to 18 days following the concrete placement (to eliminate much of the shrinkage cracking) such that the minimum compressive stress in the concrete exceeds 50 pounds per square inch. Stressing should be completed before structural loads are applied to the slabs.

8-3. Drilled shaft foundations

Items in table 8-3 should be checked to minimize defective shaft foundations. The foundation engineer should visit the construction site during boring of the first shaft holes to verify the assumptions regarding the subsurface soil profile, e.g., the nature and location of the subsoils. Periodically, he or she should also check the need for the designer to consider modifications in the design.

a. Location of shaft base. The base of the shaft is located in the foundation soils to maintain shaft movements within tolerable limits. This depth depends on the location and thickness of the expansive, compressible or other unstable soil, sand lenses or thin permeable zones, depth to groundwater, and depth to foundation soil of adequate bearing capacity. The design depth may require modification to relocate the base in the proper soil formation of adequate bearing capacity and below the active zone of heave. The purpose of locating the base of the shaft in the proper soil formation should be emphasized to the inspector during the first boring of the drilled shaft foundation. Underreams may be bored in at least l.5-foot-diameter (preferably 2.5-foot) dry or cases holes where inspections are possible to ensure cleanliness of the bottom.

b. Minimization of problems, Long experience has shown that drilled shaft foundations are reliable and economical. Nevertheless, many problems are associated with these foundations and can occur from inadequate understanding of the actual soil profile and groundwater conditions, mistakes made while drilling, inadequate flow of concrete, and improper reinforcement.

(1) *Inadequate information.*

(a) Site conditions should be known to permit optimum selection of equipment with the required mobility.

(b) Subsurface conditions should be known to permit selection of equipment with adequate boring capacity.

(c) Type of soil (e.g., caving and pervious strata) may require slurry drilling. Specifications should permit sufficient flexibility to use slurry for those soil conditions where it maybe needed.

(d) Previously unnoticed sand lenses or thin permeable zones in otherwise impervious clay may cause problems during construction of drilled shafts. Seepage through permeable zones may require casing or slurry and may render construction of an underream nearly impossible.

(e) Overbreak or the loss of material outside of the nominal diameter of the shaft due to caving soil is a serious problem that can cause local cavities or defects in the shaft. The construction procedure (boring dry, with casing, or using slurry) should be chosen to minimize overbreak.

(2) *Problems with the dry method.* Caving, squeezing soil, and seepage are the most common problems of this method. Stiff or very stiff cohesive soils with no joints or slickensides are usually needed. Underreams are vulnerable to caving and should be constructed as quickly as possible.

(3) *Problems with the casing method.* Slurry should be used while drilling through caving soil prior to placement of the casing and sealing of the casing in an impervious layer. An impervious layer is necessary to install the bottom end of the casing.

(a) Casing should not be pulled until the head of concrete is sufficient to balance the water head external to the casing; otherwise, groundwater may mix with the concrete.

(b) Squeezing or localized reduction in the borehole diameter on removal of the casing can be minimized by using a relatively high slump concrete with a sufficient pressure head.

(c) Casing sometimes tends to stick in place during concrete placement. If the concrete appears to be setting up, attempts to shake the casing loose should be abandoned and the casing left in place to avoid the formation of voids in the shaft when the casing is pulled.

(d) Steel reinforcement should be full length to avoid problems in downdrag of the reinforcement while the casing is pulled. The reinforcement cage should also be full length if uplift forces are expected on the drilled shaft from swelling soil.

(4) *Problems with the slurry method.* Slurry of sufficient viscosity is used to avoid problems with caving soils. A rough guide to appropriate slurry viscosities is given by a Marsh cone funnel test time of about 30 seconds for sandy silts and sandy clays to 50 seconds for sands and gravels. The Marsh cone test time is the time in seconds required to pour 1 quart of slurry through the funnel. The workability of the slurry should also be adequate to allow complete displacement of the slurry by the concrete from the perimeter of the borehole and steel of the rebar cage.

(a) Slurries should be of sufficient viscosity to eliminate settling of cuttings. Loose cuttings adhering to the perimeter of the hole can cause inclusions and a defective shaft.

(b) The tremie sometimes becomes plugged, stopping the flow of concrete into the borehole. The tremie should not be pulled above the concrete level in the shaft before the concrete placement is completed, otherwise inclusions may occur in the shaft following reinsertion of the tremie into the concrete.

(c) The reinforcement cage may move up if the tremie is too deep in the concrete or the concrete is placed too rapidly.

c. Placement of concrete. Concrete strength of at least 3,000 pounds per square inch should be used and placed as soon as possible on the same day as drilling the hole. Concrete slumps of 4 to 6 inches and limited

aggregate size of one third of the rebar spacing are recommended to facilitate flow of concrete through the reinforcement cage and to eliminate cavities in the shaft. Care should be exercised while placing the concrete to ensure the following:

(1) Continuity while pulling the casing.

(2) Tip of tremie always below the column of freshly placed concrete in wet construction; no segregation in a dry hole.

(3) Adequate strength of the rebar cage to minimize distortion and buckling.

Table 8-1. Considerations for Inspection

	Construction
Excavation	1. Bracing system. 2. Tie backs. 3. Dewatering. 4. Retaining structures. 5. Protection from drying of temporarily exposed surfaces of expansive clay.
Effects on surrounding structures	1. Retaining walls and lost ground. 2. Slope stability, erosion, and soil stabilization. 3. Surface and subsurface drainage. 4. Foundation movement and fracture of adjacent (nearby older structures).
Maintenance	1. Broken or leaking water, sewer, and other utility lines. 2. Surface drainage system. 3. Vibration effects from adjacent (nearby) structures. 4. Changes in groundwater.
	Postconstruction
	1. Broken or leaking water, sewer, and other utility lines. 2. Surface drainage system. 3. Foundation movement and fractures in the new structure. 4. Vibration effects from adjacent (nearby) structures. 5. Changes in groundwater. 6. Heavy vegetation near the structure.

Table 8-2. Inspection of Reinforced Slab Foundations

Site preparation	1. Proper selection of materials. 2. Proper compaction of fill. 3. Proper backfill of plumbing trenches and holes due to removal of trees. 4. Proper cleanout of trenches for reinforcing beams. 5. Proper slope of trenches. 6. New excavations coated with sprayed asphalt or sealing surface to prevent drying of the exposed excavation surface. 7. Proper beam size and spacing. 8. Proper slab thickness.
Membrane placement	1. Moisture barrier contoured to the shape of the trench to eliminate voids between the trench and bottom of the membrane. 2. Elimination of punctures, holes, and leaks in the membrane.
Steel placement	1. Proper location of steel reinforcing bars and wire mesh. 2. Proper placement of tensioning rods and anchors. 3. Proper reinforcement size. 4. Adequate forming and means to hold post-tensioning anchorage assemblies in place.
Concrete placement	1. Mixture as specified (e.g., approved components in mixture, desired slump of concrete, no extra water added to mixture, proper conveying, placing and vibrating of concrete, and finishing). 2. Reinforcement not displaced by concrete. 3. Provide adequate curing for slab. 4. Obtain desired early age strength of concrete before form removal and before allowing traffic on the slab.

Table 8-2. Inspection of Reinforced Slab Foundations—Continued

Post-tensioning	1. Verify all tendons stressed according to specification and within 3 to 10 days of the concrete placement. 2. Ends of properly stressed tendons cut off, pockets grouted, and any necessary repairs made. Improperly stressed tendons must not be cut off.

Table 8-3. Inspection of Drilled Shafts

Drilling	1. Proper shaft dimensions. 2. Collapse of hole. 3. Proper cleanout of hole of loose cuttings and weak soil.
Dry method	1. Loose cuttings in the hole. 2. No more than 2 to 3 inches of water at the bottom if end bearing. 3. Concrete not strike the shaft perimeter if free fall (ACI 304-73 recommends that concrete should be deposited at or near its final position such that the tendency to segregate is eliminated when flowing laterally into place). 4. Adequate vibration provided to consolidate concrete around reinforcement.
Casing method	1. Clean and undeformed casing before concrete placement. 2. Sufficient concrete placed to balance the external pressure head before the casing is pulled.
Slurry method	1. Viscosity of slurry adequate to be displaced from the perimeter of the hole and the reinforcing steel by the concrete. 2. Clean-out bucket used to clean the bottom prior to concreting. 3. Bottom of the tremie pipe maintained in fresh concrete at all times after placement has begun. The deeper the embedment in concrete the flatter the finished slope will be.
Underreams	1. Minimal cuttings in the bottom (at least 75 to 80 percent of the bottom free of cuttings). 2. Adequate bell diameter (check travel of the kelly on the ground surface when the reamer is extended to the proper bell diameter).
Concrete placement	1. No segregation during placement. 2. Concrete never to be poured through water. 3. Adequate slump (avoid hot concrete). 4. Maximum aggregate size not too large for reinforcement.
Reinforcement cage	1. Resistance to buckling during the concrete placement. 2. Full length if casing used. 3. Restriction to flow of concrete through the cage. 4. Restrained from movement during concrete placement. 5. Proper position of the cage.